REMARKS ON THE QUESTION OF INTERCALATION OF VERTEBRAE.

G. BAUR.

PROFESSOR H. C. BUMPUS ('97) has published in the last number of the *Journal of Morphology*, vol. ii, No. 2, February, 1897, a paper on the skeletal variations of *Necturus maculosus* Raf.[1] Radiographs of one hundred alcoholic specimens were prepared, and the variations of the number of vertebrae with reference to the position of the sacrum were determined. G. H. Parker ('96, pp. 711–717) had already examined 27 specimens and found the following variations :

The pelvis is attached to the 19th vertebra in 19, to the 20th vertebra in 6 specimens. In one case the 19th vertebra had a well-developed sacral rib on the left side, the right sacral rib being on the 18th vertebra. In another specimen the sacral ribs were on the 20th on the left and on the 21st vertebra on the right side. Among these 27 specimens were found, therefore, two with asymmetrical sacral vertebrae, to which the pelvis was attached obliquely.

Bumpus' results are the following:

Number of Specimens.	Number of Presacral Vertebrae.	Sacral Vertebra. Ribs attached at the	
		Left.	Right.
64	18	19	
28	19	20	
7	18	19	20
1	18	20	19

[1] "*Maculosus*" is the correct name given by Rafinesque in the *American Monthly Magazine* and *Critical Review*, vol. iv, No. 1, New York, November, 1818, p. 41 (*Sirena maculosa*). In 1819 he called it *Necturus maculatus*, *Journ. de Physique*, vol. 88, 1819, p. 418, and in 1820 *Necturus maculosus*, Annals of Nature, or Annual Synopsis of New Genera and Species of Animals, Plants . . . Discovered in North America by C. S. Rafinesque. First annual number, for 1820. Transylvania University, March 1, 1820, Lexington, Ky.

In 127 specimens the ilium was therefore attached either to the 19th vertebra 83 times, or to the 20th 34 times, or to the 19th and the 20th obliquely 8 times, or to the 20th and 21st obliquely once.

The reason of this variation is this: The ilium is attached very loosely to the sacral ribs by ligament, as in *Proteus* and *Amphiuma*. There are no distinctly modified sacral vertebrae, and hence it is not surprising at all that the ilium is not attached always to the same vertebra. The sacral region has not the power of developing sacral ribs at several points on both right and left sides, but the pelvis may attach itself — for it becomes secondarily united with the vertebral column — to any of the vertebrae of the pelvic region. In *Necturus* we have all the variations possible for the attachment of two consecutive vertebrae, the 19th and 20th; only in one case the ilium reaches the 21st vertebra, and in this case the pelvis is oblique.

The Amphibia are descended from fishes in which the pelvis is never in connection with the vertebral column. In *Necturus* and *Proteus* the ilium is very loosely connected with the distal processes of the sacral ribs. *Necturus* and *Proteus* belong to the *Proteida*, the only group of living Amphibia with a free paroccipital [opisthotic]. The attachment of the ilium to a definite vertebra has not yet become constant. If one hundred specimens of a lizard, of a crocodile, or of a turtle should be examined, exceedingly few variations would be found. The great variability in the attachment of the pelvis to the vertebral column in the tailed Amphibia is a result of the loose connection between both. Very many more cases of asymmetrical sacra have been described in the tailed Amphibia, than stated by Parker, who knows only that of Lucas ('**86**, p. 561) in *Cryptobranchus* (*Menopoma*). They were described as early as 1818 in *Triturus* (*Molge*) *cristatus* Laur. by C. A. S. Schultze ('**18**, p. 379), and in 1825 by Cuvier ('**25**, p. 414); in *Triturus vulgaris* L. and *Salamandra salamandra* L. (*maculosa* Laur.) by Claus in 1876 ('**76**, p. 23); in *Megalobatrachus maximus* Schlegel by Schmidt, Goddart, and Van der Höven in 1862 ('**62**), by Claus in 1876 ('**76**, p. 29); in *Cryptobranchus* (*Menopoma*)

alleghaniensis Daudin, by Mayer in 1835 ('**35**, p. 78), Hyrtl in 1864 ('**64**, pp. 264–272), and Claus in 1876 ('**76**, p. 29).

Nearly all these cases have been recorded by Claus in 1876 in an excellent paper: "Verschiebungen des Darmbeins und der Sacralregion der Wirbelsäule von Amphibien." This very important paper has been overlooked by both Parker and Bumpus. Claus says: "Unter Ausschluss des ersten als Halswirbel zu bezeichnenden Wirbels und des letzten oder Sacralwirbels repräsentirt die Wirbelsäule des Rumpfes [bei den geschwänzten Amphibien] eine gleichmässig gestaltete Dorsolumbalregion von mächtiger Ausdehnung, *deren hintere Grenze aber bei der Verschiebung und Lagenveränderung des zum Os ileum bezogenen Sacralwirbels nach der Caudalregion hin keineswegs unveränderlich, vielmehr mannigfachen Schwankungen ausgesetzt ist.* Für diese thatsächlich stattfindende Bewegung des Darmbeines in der hinteren Grenzgegend des Rumpfes glaube ich eine Reihe unzweideutiger Beweise vorlegen zu können. Anstoss zu den mitzutheilenden Beobachtungen gab mir der Vergleich von zwei in der hiesigen [Wiener] Sammlung aufgestellten Menopomaskeleten, von denen das eine die von Hyrtl beschriebene asymmetrische Gestaltung des vorderen Caudalwirbels zeigt. Diese und ähnliche für mehrere Eidechsen nachgewiesenen Asymmetrien, diez war unter dem Begriff der 'Assimilation' subsummirt, damit aber in ihrer Bedeutung noch keineswegs verstanden waren, legten mir den Gedanken nahe, dass es sich bei diesen Bildungen nicht etwa um *abnorme Missgestaltungen*, sondern um *allmälige Verschiebungen des Os ileum handelt*, welche ein Vorwärtsrücken des Kreuzbeins vorbereiten; und mit einer regelrechten Lageveränderung desselben als Uebergangsstufen in Verbindung zu bringen sein möchten."

We see that Claus had fully recognized the true nature of these conditions. The following is a table compiled from different authors; many of these cases have been recorded by Claus.

All the variations in the position of the sacral vertebra given in this list are produced by the shifting of the pelvis.[1]

[1] The same conclusion was reached by Jhering in his study of the spinal nerves, Ueber das peripherische Nervensystem der Wirbelthiere, Leipzig, 1878.

VARIATIONS IN THE PRESACRAL AND SACRAL VERTEBRAE IN THE CAUDATA.[1]

GENERA AND SPECIES.	NUMBER OF SPECIMENS.	NO. OF PRESACRAL VERTEBRAE.	SACRAL VERTEBRA. NO. SACRAL RIBS ATTACHED AT THE RIGHT.	LEFT.	AUTHOR.	DATE.
Triturus cristatus Laur.	1	15	16	17	Schultze	1818
Triturus Rafinesque, 1819, for *Triton* Laurenti, 1768, preoccupied by	1	16	17		Cuvier	1825
Triton Linné.	3 { 1	16	17		Wiedersheim ('75, p. 116)	1875
Molge Merrem, 1820.	1	16	17		Claus	1876
	1	16	17	18	Cuvier	1825
	1	17	18		Cuvier	1825
	1	18	19		Claus	1876
Triturus vulgaris Linn. (taeniatus Schneid.)	1	13	15	14	Claus	1876
	4 { 1	15	16		Wiedersheim	1875
	4 { 3	15	16		Claus	1876
Triturus palmatus Schneid.	4 { 1	13	14		Wiedersheim	1875
(*helveticus* Leydig)	4 { 3	13	14		Claus	1876
Salamandra salamandra Linn.	2	14	15		Claus	1876
(*S. maculosa* Laurenti, 1768)	9 { 1	15	16		Cope ('89, pl. XXXVIII)	1889
	9 { 8	15	16		Claus	1876
	2	15	16	16	Claus	1876
				17		
	1	15	16	17	Claus	1876
	1	16	17		Claus	1876
Salamandra atra Laur.	4 { 3	15	16		Claus	1876
	4 { ?	15	16		Cuvier	1825
	?	16	17		Cuvier	1825

Diemyctylus torosus Eschsch. (Taricha torosa)	3	13	14	Claus	1876
Pleurodeles waltlii Michah.	5	15	16	Claus	1876
Amblystoma punctatum Linn. (Salamandroides venenosus, Daud.	4 { 3	15	16	Claus	1876
Amblystoma argus, Dum. et Bibr.)	4 { 1	15	16	Cope ('89, pl. XIV and XV)	1889
Chondrotus tenebrosus Baird and Gir.	1	15	16	Cope ('89, pl. XXII and XXIII)	1889
Amblystoma tigrinum Green (Siredon)	3	16	17	Claus	1876
Spelerpes ruber Daud. (*Bolitoglossa rubra*, Dum. et Bibr.)	1	18	19	Claus	1876
Spelerpes porphyriticus Green. (*Spelerpes salmoneus*, Holbr.)	1	19	20	Claus	1876
Desmognathus niger Green. (*Amblystoma nigrum*, Dum. et Bibr.)	1	16	17	Claus	1876
Geotriton fuscus Bonap.	1	15	16	Wiedersheim	1875
Salamandrina perspicillata Savi.	1	14	15	Wiedersheim	1875
Necturus maculosus Raf.	2	18	19	Claus	1876
	1	18	19	Hoffmann ('73, p. 52)	1873
	1	19	20	Cope ('89, pl. I)	1889
	1	19	21 20	Mayer ('35, p. 78)	1835
Cryptobranchus alleghaniensis Daud.	4 { 3	19	20	Claus	1876
	4 { 1	19	20	Cope ('89, pl. V and VI)	1889
	2 { 1	19	20 21	Hyrtl	1864
	2 { 1	19	20 21	Claus	1876
	1	19	20 20 21 21	Huxley ('78, p. 752)	1878
	1	9 1	20 21 21	Lucas ('86, p. 561)	1886
	1	20	21	Claus	1876

[1] *Caudati* (Urodèles), Duméril, 1806; *Ecaudati* (Anoures), Duméril, 1806. (Duméril, A.M., Constant. Zoologie Analytique, ou Méthode Naturelle de Classification des Animaux, Paris, MDCCCVI, pp. 90, 91, 94, 95.)

VARIATIONS IN THE PRESACRAL AND SACRAL VERTEBRAE IN THE CAUDATA. — *Continued.*

GENERA AND SPECIES.	NUMBER OF SPECIMENS.	NO. OF PRESACRAL VERTEBRAE.	SACRAL VERTEBRA. NO. SACRAL RIBS ATTACHED AT THE RIGHT.	LEFT.	AUTHOR.	DATE.
Andrias scheuchzeri Holl	1	20	21		von Meyer ('45, pl. X)	1845
Andrias tschudii v. Meyer	1	21	22		von Meyer ('60, pl. IX, fig. 1)	1860
Megalobatrachus maximus Schlegel	1	19	20		Claus	1876
	1	20	21		Claus	1876
	1	20	21		Baur	
	1	20	21		Claus	1876
			united with first caudal		Schmidt, Goddart, und van der Höven ('62)	1862
	2 { 1	20	22	21		
	2 { 1	20	22	21	Claus	1876
	1	21	22		Schlegel ('38)	1838
	1	21	22		Hyrtl ('65, p. 43)	1865
Proteus anguineus Laur.	1	29	30		Hyrtl ('65, p. 43)	1865
	1	29	30		Hoffmann	1873
	1	30	31		Cuvier ('45, p. 429)	1825
Amphiuma tridactyla Cuv.	1	62	63		Hyrtl	1865
Amphiuma means Garden	1	62	63		Cope ('89, pl. X)	1889

The most striking case of increase of presacral vertebrae during the ontogeny of one species is shown by *Branchiosaurus amblystomus* Cred., a Stegocephalian from the Permian of Germany. The number of the presacral vertebrae is smaller in the younger specimens, and gradually increases until the adult stage is reached. Credner ('**86**, p. 620) gives the following table:

Length of Vertebral Column from Posterior Border of Skull to the Anterior End of the Sacral Vertebra.	Number of Presacral Vertebrae.
19	20
23	20
25	20
26	20
27	20
28	21
30	21
32	21
33	21
37	22
39	23 or 24
43	25 or 26
48	25 or 26
50	26
52	26
54	26 or 27
56	26 or 27

We have here the highest number of sacral variations that has been observed.

Having considered the Amphibia, we may now pass over to the Reptilia. Hyrtl ('**64**, pp. 264–272) has described in 1864 asymmetrical sacra in the following lizards: *Lophura amboinensis* Schlosser, *Amphibolurus* (*Grammatophora*) *barbatus* Cuv., and *Tupinambis* (*Ctenodon*) *nigropunctatus* Spix. In the living Crocodilia the number of the presacral vertebrae is 24, which are all procoelous or concave-convex. There are two sacrals: the first one is concave-plane, the second plane-convex, and the first caudal is biconvex; all the following caudals are like the cervicals, procoelous.

Among eleven skeletons Reinhardt ('**73**, pp. 221–228) found three with three sacral vertebrae.

1. *Caiman sclerops* Schneid. The last lumbar is transformed into a sacral. There are only 23 presacral vertebrae.

2. *Crocodilus americanus* Laur. (*acutus* Cuv.). There are three sacrals; the first two are the normal; the first is concave-plane, the second plane-plane, and the third plane-convex; all the following are procoelous, and the first bears a chevron. The first caudal has been taken up by the sacrum. There are, however, only 23 presacral vertebrae.

3. *Crocodilus americanus* Laur. Three sacrals. The first caudal is transformed into a sacral vertebra, and there are 24 presacral vertebrae.

4. Another case with three sacral vertebrae has been described by Case ('**96**, pp. 231–233). There are 24 presacral vertebrae. The 25th has the sacral ribs inclined backwards and becoming slender. The 26th has strong thick ribs; and the 27th has also well-developed ribs articulating with the ilium. This vertebra is seemingly biconvex. The first chevron is attached between the 28th and 29th. The first caudal has been taken up into the sacrum. Both sides are symmetrical.

5. I have described a case in *Alligator mississippiensis* Daud. The last lumbar possesses small sacral ribs, which, however, do not reach the ilium. In front of this there are 23 presacral vertebrae ('**86**, p. 690).

6. *Crocodilus americanus* Laur (*acutus* Cuv.), No. 129, B. Museum, Cambridge, England. The 25th vertebra has a strong presacral rib on the right side; it is much weaker on the left, and united with the center. The 26th shows typical sacral ribs; the 27th bears on the left side a strong free sacral rib, on the right side a weaker rib but free. The ilium is supported on the left principally by the 25th and 26th, at the right by the 26th and 27th vertebrae. The 28th is biconvex. Here we have an asymmetrical sacrum. This case was published by me in 1889 ('**89**, p. 240).

7 and 8. In two specimens of *Crocodilus porosus* Schneid. (*biporcatus* Cuv.) in the Reichsmuseum of Leyden there are only 23 presacral vertebrae ('**89**, pp. 240, 241).

In all these cases we have shifting of the pelvis.

Professor Bumpus does not believe in intercalation, but there are true cases of intercalation, as I shall show. The Gavial case has been accepted by Parker, but not by Bumpus. The original description was published in 1886 ('**86**, p. 689, also '**91**, p. 334). "Bei einem Exemplar von *Gavialis gangeticus* finde ich 25 praesacrale Wirbel; zwischen dem 9. und 10. Wirbel ist ein solcher eingeschaltet, wie aus der Configuration der Dia- und Parapophysen genau bestimmt werden kann." It is a well-known fact that in all living Crocodilia with normal vertebral column there are 24 presacral vertebrae, two sacrals, and many caudals. All the presacral vertebrae are concave-convex; the first sacral is concave in front, plane behind; the second plane in front, concave behind; the first caudal is biconvex. In the Gavial with 24 presacrals and the Gavial with 25 presacrals, the two sacrals and the first caudal are absolutely identical in structure. In the first case the first caudal is the 27th, in the second the 28th. Therefore one vertebra must have been intercalated between two of the 24 presacral vertebrae. I determined these vertebrae as the 9th and 10th. Here are my reasons. It is very well known that the vertebrae of the Crocodilia are very different in form, passing from the atlas to the sacrum, and these differences have been very well described by Huxley in his *Anatomy of Vertebrates* (1871). Omitting a consideration of the first two vertebrae, the atlas and axis, concerning the identity of which there can be no doubt in the two specimens, we may examine the following vertebrae. The other cervicals all possess ribs with distinct and long capitula and tubercula — the latter attached above the neurocentral suture to the neural arch, the former to the centrum below the neurocentral suture. The body of each cervical rib, after the second and as far as the seventh and eighth, is short and prolonged in front of, as well as behind, the junction of the capitulum with the tuberculum; and the several ribs lie nearly parallel with the vertebral column and overlap one another. The ribs of the eighth vertebra are a little longer than those of the seventh; the ninth rib is very much longer than the eighth, and has a terminal cartilage.

The points to which the capitula and tubercula of the ribs are attached are raised into tubercles, and by degrees these become elongated into distinct capitular and tubercular processes, — diapophysis and epapophysis, — between which in the third to the tenth vertebrae, the neurocentral suture passes. In the ninth and the tenth the diapophysis ascends to the level of the neurocentral suture, and in the eleventh it ascends with its upper half to the neural arch, being traversed by the neurocentral suture. At the same time the epapophyses become more and more elongated. In the twelfth vertebra a sudden change in the character of the transverse processes takes place. There is no true diapophysis any longer ; the capitulum is also connected with the long epapophysis at the anterior middle portion. In all the following vertebrae up to the lumbar region the ribs are connected with the strong epapophyses. *In all the Crocodilia the first vertebra which carries the ribs completely on the transverse process, is always the twelfth.* In *Gavialis*, with 25 presacral vertebrae, it is the thirteenth. There are 12 vertebrae behind this one in all the Crocodilia and the abnormal Gavial; therefore in front of this one a vertebra must have been added. By careful comparison it was found that this additional vertebra is intercalated between the ninth and tenth. The vertebra resembles the ninth and tenth in having the capitulum completely placed on the center just on the level of the neurocentral suture. In all the Crocodilia there are two such vertebrae; in the abnormal Gavial, three. In this case we have no shifting of the pelvis, but true intercalation.

In my paper on intercalation I made the following remark : "If intercalation takes place at all, we ought to expect traces of it in such forms which show a great increase in the number of vertebrae, for instance, snakes, different families of lizards, and plesiosaurs" ('**91**, p. 333). The enormous number of 435 of the vertebrae in *Python molurus* Linn. has certainly not been reached by adding vertebrae at the distal end, but by the intervertebral increase of the smaller numbers. It is evident that intercalation can only be proved by the presence of half-divided vertebrae, and it is very interesting, and certainly not accidental, that in snakes such half-divisions have been observed quite frequently.

Python molurus Linn. (*P. tigris* Daud). In a skeleton of this snake in the Museum of the Royal College of Surgeons of England in London, No. 602, the following peculiarities of structure are to be seen. Up to the 147th inclusive the vertebrae are normal, each having a pair of transverse processes and a pair of ribs. The next vertebra is normal anteriorly, and as far as the level of the posterior surface of the transverse processes, save that its neural spine is rather small from before backwards. The transverse processes bear a pair of normal ribs. But behind this pair of transverse processes the parts begin again, rising again into a neural spine, and growing outwards into a second pair of transverse processes, with a second pair of normal ribs. Posteriorly again the parts are normal. These two segments are not the result of ankylosis, but of imperfect, division.

In the same specimen the 166th vertebra is normal on the left side, bearing one transverse process and one rib, while on the right side there are *two* complete transverse processes and *two* ribs. The 185th shows the same condition, being double on the right side and single on the left. (Owen, 1853, p. 123; Baur, 1889, p. 333; Bateson, 1894, pp. 103–105.)

Python sebae (Gmelin), Museum Brussels. The 195th vertebra is single on the right side, and double with two ribs on the left. Besides 195 is ankylosed with 196. (Albrecht, 1883, pp. 21–34, Pl. II, Figs. 1–4; Fürbringer, 1888, vol. ii, pp. 975, 976 ; Baur, 1889, p. 332; Bateson, 1894, p. 105.)

Python sp., Cambridge University Museum. 168th vertebra double on the left side. (Bateson, 1894, p. 105.)

Hydrus platurus Linn. (*Pelamis bicolor* Daud), No. 763, Yale University Museum. The 212th vertebra simple on the left side, with one rib; double on the right side, with two ribs. (Baur, 1889, p. 333.)

Cimoliasaurus plicatus Phillips (Plesiosauria), No. 48,001, British Museum, London. Cervical vertebra divided on one side with two ribs. (Lydekker, 1889, p. 238; Baur, 1889, p. 333; Bateson, 1894, p. 105.)

In *Python* there may be as many as 435 vertebra, and in *Cimoliasaurus plicatus* we have 44 cervicals.

The increase of the number of cervical vertebrae in the Plesiosauria is certainly not produced by a shifting backwards of the shoulder girdle, but by addition of new vertebrae by intercalations, as will be seen from the following table:

TABLE SHOWING THE NUMBER OF VERTEBRAE IN PLESIOSAURIA.

	CERVICALS.	DORSALS.	SACRALS.	CAUDALS.
PLIOSAURIDAE				
Pliosaurus evansi Seeley	19–20			
Peloneustes philarchus Seeley	20–21			
PLESIOSAURIDAE				
Plesiosaurus rostratus Owen	28	20	2	34
Plesiosaurus macrocephalus Owen	30	20	2	18+*
Thaumatosaurus megacephalus Stutchbury	30	26	2	34
Plesiosaurus hawkinsi Owen	31	23	2	—
Cryptoclidus oxoniensis Phillips	31	23	2	23+
Plesiosaurus guilelmi-imperatoris Dames	35	20	2	37
Plesiosaurus conybeari Sollas	38	21	2	5+
Plesiosaurus homalospondylus Owen	38	22	2	25+
Plesiosaurus dolichodeirus Conybeare	41	21	2	30+
Muraenosaurus plicatus Phillips	44			
ELASMOSAURIDAE				
Elasmosaurus platyurus Cope	72	20	2	23+

Everybody who will examine this table must admit that the increase of the number of cervical vertebrae can only be explained by intercalation. We see, therefore, that intercalation really occurs.

All the cases enumerated in the table of the Amphibia caudata and the cases of the Crocodilia demonstrate the shifting of the pelvis, a process which I have always admitted.

In the Ecaudata (Batrachia) we find the same processes, as has been shown in an excellent paper just published (after I had written my paper) by W. G. Ridewood, "On the Development of the Vertebral Column in Pipa and Xenopus," *Anat. Anz.*, xiii, Bd. 10, April 1897, No. 13, pp. 359–376, with 4 figures.

* + means that the tail is not completely preserved.

Ridewood has discussed fully all the known cases of variation in the number of presacral vertebrae in the Ecaudata. He makes the following remarks (p. 366): "Throughout the whole group of the Anura (Ecaudata) the number of presacral vertebrae, and consequently the morphological position of the sacrum, is remarkably constant; and the wonder is that variations and abnormalities are not more common. When variation in the number of presacral vertebrae does occur, the explanation is to be sought, not in the intercalation or excalation of vertebrae, which, as Parker ('96) has already pointed out, are to be looked upon as very rare occurrences, but rather in the shifting of the ilium forwards or backwards on to the vertebra in front of or behind the normal. The vertebrae are from their mode of development intimately connected with the myotomes of the body, but the pelvis is less directly influenced by the primitive segmentation. It is a matter of little import whether it develops a little in front of or a little behind its normal position, and, in whatever position it develops, it seeks to gain attachment to that part of the axial skeleton which happens to be nearest. The vertebrae respond, and their lateral parts become modified accordingly in size and shape.

"In Anura (Ecaudata) those diapophyses which, during development, happen to come nearest to the upper extremities of the ilia enlarge in anticipation long before they come into actual contact with the pelvis. The diapophyses so affected are usually those of the ninth vertebra, and so this has come to be regarded as the normal sacral vertebra; but it may be those of the eighth or the tenth, or even a combination of these, forming a compound sacrum. The tenth vertebra is, like those succeeding, only 'potential,' and as a rule does not differentiate; but when from proximity of the ilium an additional strain is thrown upon the resources of the somite, its latent capacity for development is awakened, and a well-formed vertebra with strong diapophyses results.

"*As soon as we admit that, in Anura at least, any vertebra can become sacral, and that it only requires the stimulating presence of the iliac cartilages to induce an exaggerated development of the diapophyses, all the mystery of abnormal sacra is dispelled,*

whether the abnormality is due to the asymmetry, or to the compound nature of the sacrum, or to a combination of these."

With these very pertinent remarks I close this paper.

UNIVERSITY OF CHICAGO,
LABORATORY OF PALAEONTOLOGY, May 6, 1897.

BIBLIOGRAPHY.

1883. ALBRECHT, PAUL. Note sur une hémivertèbre gauche surnuméraire. de *Python Sebae* Duméril. *Bull. Mus. Roy. Hist. Nat. d. Belgique* Tome ii. 1883. pp. 21–34, Pl. II, Figs. 1–4. Bruxelles, 1883.

1894. BATESON, WILLIAM. Materials for the Study of Variation. London, 1894. pp. 103–105, Fig. 10, I, II, pp. 123, 124.

1886. BAUR, G. Osteologische Notizen über Reptilien. *Zool. Anz.* ix. Jahrgang, 1886. No. 238, pp. 689, 690.

1889. ——— Revision meiner Mittheilungen im Zoologischen Anzeiger, mit Nachträgen. *Zool. Anz.* xii. Jahrgang, 1889. No. 306, pp. 240, 241.

1891. ——— On Intercalation of Vertebrae. *Journ. of Morph.* Vol. iv, No. 3. Boston, 1891. pp. 331–336.

1897. BUMPUS, HERMON C. A Contribution to the Study of Variation (Skeletal Variations of Necturus maculatus Raf). *Journ. of Morph.* Vol. xii, No. 2. February, 1897. pp. 455–478, Pls. *A*, *B*, and *C*.

1896. CASE, E. C. Abnormal Sacrum in an Alligator. *Amer. Nat.* March, 1896. pp. 232–234. 2 figures.

1876. CLAUS, C. Beiträge zur vergleichenden Osteologie der Vertebraten. 1. Rippen und unteres Bogensystem. 2. Verschiebungen des Darmbeins und der Sacralregion der Wirbelsäule von Amphibien. *Sitzungsb. d. k. Akad. d. Wiss., math.-nat. Classe.* Bd. lxxiv, Abt. i. 1875. pp. 785–818, Pls. I–III. Wien, 1876.

1889. COPE, E. D. The Batrachia of North America. Washington, 1889. Pls. 1, 5, 6, 10, 14, 15, 22, 23, 37, Fig 1.

1886. CREDNER, HERMANN. Die Stegocephalen aus dem Rothliegenden des Plauenschen Grundes bei Dresden. vi. Theil: Die Entwicklungsgeschichte von *Branchiosaurus amblystomus* Cred. *Zeitschr. deutsch. Geol. Ges.* Jahrgang 1886, pp. 576–633, Taf. XVI–XIX, und 13 Textfiguren.

1825. CUVIER, G. Recherches sur les Ossemens Fossiles. Tome v. 2 me Partie. Paris, 1825. pp. 413, 414, 429.

1888. FÜRBRINGER, MAX. Untersuchungen zur Morphologie und Systematik der Vögel. Amsterdam, 1888. Vol. ii, pp. 972–991.

1873. HOFFMANN, C. K. Amphibien in Bronn's Klassen und Ordnungen. 1873. pp. 51, 52.

1875. HUXLEY, T. H. Article "Amphibia" in *Encyclopaedia Britannica*. Ninth ed. Vol. i, p. 752, Fig. 2, *A* and *B*.

1864. HYRTL, JOSEPH. Ueber Wirbelassimilation bei Amphibien. *Sitzungsb. d. k. Akad. d. Wiss., math.-nat. Classe.* Bd. xlix. Wien, 1864. pp. 264–272.

1865. ——— Cryptobranchus japonicus. Vindobonae, 1865. 4°. p. 43.

1878. JHERING, H. v. Ueber das peripherische System der Wirbelthiere. Leipzig, 1878.

1886. LUCAS, F. A. The Sacrum of Menopoma. *Amer. Nat.* Vol. xx, p. 561. 1886.

1889. LYDEKKER, RICHARD. Catalogue of the Fossil Reptilia and Amphibia in the British Museum. Part ii. London, 1889. p. 238.

1835. MAYER, A. F. J. C. Analecten für vergleichende Anatomie. Bonn, 1835. p. 78.

1845. MEYER, HERMANN VON. Zur Fauna der Vorwelt. Fossile, Säugethiere, Vögel und Reptilien aus dem Motasse-Mergel von Oeningen. 1845. Taf. 10.

1860. ——— Salamandrinen aus der Braunkohle am Rhein und in Böhmen. *Palaeontographica.* Bd. vii, pp. 47–73. 1860.

1853. OWEN, A. Descriptive Catalogue of the Osteological Series Contained in the Museum of the Royal College of Surgeons of England. Vol. i, p. 123. London, 1853.

1896. PARKER, G. H. Variations in the Vertebral Column of Necturus. *Anat. Anz.* Bd. xi. 1896. pp. 711–717. 2 figures.

1873. REINHARDT, J. Anomalier i krydshvirvlerne hos krokodilerne. *Videnskab. Meddel. fra d. naturhist. Foren.* Kjöbenhavn (Aaret, 1873), 1873–74. pp. 221–228. Also abstract in Gervais: *Journal de Zoologie.* iii. 1874. pp. 308–312.

1833. SCHLEGEL, H. Les Batraciens in Phil. Frz. de Siebold, Fauna Japonica. Fol. maj. Lugduni Batav. 1833. p. 132, Pl. VIII.

1862. SCHMIDT, F. J. J., AND J. GODDART, en J. van der Hoeven, jun. Aanteekeningen over de Anatomie van den *Cryptobranchus japonicus. Naturk. Verhand. Holl. Maatsch. d. Wetensch.* Harlem. xix deel 1 stuck. 1862.

1818. SCHULTZE, C. A. S. Ueber die ersten Spuren des Knochensystems und die Entwicklung der Wirbelsäule in den Thieren. J. F. Meckel, *Deutsch. Arch. f. d. Physiol.* Bd. iv, Heft 3. 1818. p. 379, Anmerkung.

1875. WIEDERSHEIM, ROBERT. Salamandrina perspicillata und Geotriton fuscus. Versuch einer vergleichenden Anatomie der Salamandrinen. Genua, 1875. p. 116.